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Thermomechanical Analysis of Carbon-Carbon Composites Evaluation Report

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13. ABSTRACT *(Maximum 200 words)*
A three-dimensional progressive failure analysis was developed to predict the stiffness and strength of oxidation-resistant carbon-carbon composites subjected to thermal and mechanical loads. Both plain and satin weave composites were studied. A continuum damage modeling strategy was used. However, the shapes of the predicted zones often were "crack-like". The tow crossover region was identified as a critical region for damage initiation. Matrix cracking and debonding between the tows was predicted. The fiber architecture was shown to have a large influence on stiffness, when damage occurred, and the type of damage. The analysis provides detailed information about damage initiation and growth. Of course, the predictions can be no better than the input data. The current program developed key analytical capabilities and demonstrated the sensitivity of the CC composite behavior to various parameters. To go further will require improved experimental data that will either validate the analysis or indicate aspects that require refinement

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Thermomechanical Analysis of Carbon-Carbon Composites
Evaluation Report For AASERT Grant
F49620-93-1-0471

John Whitcomb
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Center for Mechanics of Composites
Texas A & M University

Final Report
September 1, 1994 - August 31, 1997

The parent grant for this AASERT grant is AFOSR Grant F49620-92-J-0436, Structural Response of Oxidation Resistant Carbon-Carbon Components Under Cyclic and Monotonic Loading. As specified in the contract documents, the following information is supplied:

During the year prior to the ASSERT award the parent grant funding was approximately \$111.6K. Two graduate students were supported at a 50 percent rate each. It should be noted that the 50 percent rate represents full graduate student support.

During the year after the ASSERT award the parent grant funding was approximately \$107.9K. Two graduate students were supported at a 50 percent rate each.

The total funding for the AASERT grant was \$124.8K. One graduate student was supported by this grant at a 50 percent rate.

The student supported by this grant, Clinton Chapman, is a U.S. citizen.

Clinton Chapman graduated in May, 1997 with a Ph.D. in Aerospace Engineering.

The technical summary is on the next page.

Final Report

Thermomechanical Analysis of Carbon-Carbon Composites

AFOSR AASERT Grant F49620-93-1-0471

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Objective

Predict the stiffness and strength of oxidation-resistant carbon-carbon subjected to thermal and mechanical loads in an oxidizing environment

Status of effort

A three-dimensional progressive failure analysis of carbon-carbon composites was developed. To facilitate the study, various mesh generators and graphical pre- and post-processing tools were developed. These tools were used to study CC during cool-down from processing temperature and subsequent mechanical loads.

Accomplishments/New Findings

The progressive failure behavior was predicted for plain and satin weave composites. Two fiber tow shapes (which resulted in different fiber volume fractions) and two stackings (simple and symmetric) were considered for the plain weave. Details can be found in the dissertation included as part of this report and in the journal papers listed below.

The predicted stress-strain curves were bi- or tri-linear, which agrees with experimental data. The damage was predicted using a continuum damage strategy. Although this strategy uses effective properties instead on modeling discrete cracks, the shape of the predicted zones often were "crack-like". That is, there was one dimension of the zones that was much smaller than the other two. The tow cross-over region was identified as a critical region for damage initiation. Matrix cracking and debonding between the tows was predicted. The fiber architecture was shown to have a large influence on stiffness, when damage occurred, and the type of damage. The analysis provides detailed information about damage initiation and growth. Of course, the predictions can be no better than the input data. The current program developed key analytical capabilities and demonstrated the sensitivity of the CC composite behavior to various parameters. To go further will require improved experimental data that will either validate the analysis or indicate aspects that require refinement.

Peer Reviewed Publications

1. Whitcomb, J.D.; Chapman, C.: Effect of Assumed Tow Architecture and Mesh Refinement on the Predicted Moduli and Stresses in Plain Weave Composites. Journal of Composite Materials. Vol. 29, No. 16, pp. 2134-2159, 1995.

2. Whitcomb, J.D.; Srirengan, K.; Chapman, C.: Evaluation of Homogenization for Global/Local Stress Analysis of Textile Composites. Composite Structures. Vol. 31, No. 2, pp. 137-149, 1995.

3. Whitcomb, J.D.; Chapman, C.: Analysis of Plain Weave Composites Subjected to Flexure. Accepted for publication in Mechanics of Composite Materials and Structures.

4. Whitcomb, J.D.; Srirengan, K.; Chapman, C.: Modal Technique for Three-Dimensional Stress Analysis of Plain Weave Composites. Accepted for publication in Composite Structures.

Conference and Workshop Presentations

1. Whitcomb, J.D.; Srirengan, K.; and Chapman, C.: Evaluation of Homogenization for Global/Local Stress Analysis of Textile Composites. Presented at Advanced Composite Technology Mechanics of Textile Composites Workshop, March 9-11, 1994.

2. Whitcomb, J.D.; Srirengan, K.; and Chapman, C.: Evaluation of Homogenization for Global/Local Stress Analysis of Textile Composites. Presented at the AIAA/ASME/ASCE/AHS/ASC 35th Structures, Structural Dynamics, and Materials conference, Hilton Head, South Carolina, April 18-20, 1994.

3. Whitcomb, J.D.; Srirengan, K.; and Chapman, C.: Simulation of Progressive Failure in Plain Weave Textile Composites. Presented at 1994 ASME Winter Annual Meeting, Chicago, Illinois, November 13-18, 1994.

4. Chapman, C.; Whitcomb, J.D.; and Srirengan, K.: Analysis of Woven Composites Subjected to Flexure. Society of Engineering Science 31st Annual Technical Meeting, College Station, Texas, October 10-12, 1994.

5. Srirengan, K.; Whitcomb, J.D.; and Chapman, C.: Three-Dimensional Analysis of Woven Composites Subjected to Flexure. Third U.S. National Congress of Computational Mechanics, June 12-14, 1995.

6. Chapman, C.; and Whitcomb, J.D.: Thermomechanical Characterization of Plain and Satin Weave Carbon-Carbon Composites. Third U.S. National Congress of Computational Mechanics, June 12-14, 1995.

7. Whitcomb, J.D.; Srirengan, K.; and Chapman, C.: Modal Technique for Three Dimensional Stress Analysis of Plain Weave Composites. ICCM-10, Whistler, Canada, August 14-29. 1995.

8. Chapman, C.; and Whitcomb, J.D.: Strategy for Modeling Eight-Harness Satin Weave Carbon/Carbon Composites Subjected to Thermal Loads. Presented at 37th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Salt Lake City, UT, April 15-17, 1996.

9. Whitcomb, J.D.; and Srirengan, K.: Thermally Induced Damage Initiation and Growth in Carbon-Carbon Composites. Presented at the 38th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Kissimmee, FL, April 7-10, 1997.

10. Whitcomb, J.D.; and Chapman, C.: Damage Initiation and Growth in Carbon-Carbon Composites Subjected to Thermal and Mechanical Loads. Presented at the 1997 Joint ASME/ASEE/SES Summer Meeting, Chicago, IL, June 28- July 2, 1997.